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Structure and Thermal Evolution of a Metallic Glass that Grows from the Melt through a First-order Transition

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In recent decades, the structures of metallic glasses have been documented with increasing precision, and yet our understanding of these materials is still at best incomplete. The most direct proof of this is the proliferation of partially successful models attempting to classify the underlying generalized structure. To approach a more fundamental understanding of metallic glasses, it can be illuminating to investigate with care the extreme examples of a materials class. We have investigated by means of high-resolution x-ray pair-distribution function methods the structure of an unusual metallic glass that grows from the melt by a first-order phase transition in the manner of a crystal, within a prescribed AlFeSi stoichiometry, but scatters as a metallic glass. Well-defined nano domains (1.2 nm) that closely resemble atomic arrangements within alpha-AlFeSi were identified. While the alpha phase is a crystalline approximant to the neighboring icosahedral phase, the motifs in the glass structure are quite distinct from those in the icosahedral phase. Under a 305°C isothermal anneal, the glass rejects aluminum and relaxes into a more stable, longer-range order configuration that persists for hours. The quality of this glass is such that it becomes possible for the first time to approach an understanding of intermediate range packing (i.e., ordering in the range of 1–3 nm). As the anneal continues, there is a peritectic reaction in which the rejected aluminum-plus-glass undergoes a first order phase transition to a crystalline phase entirely unrelated to the nano-ordered domains in the original glass, just as if no nano ordering existed.